

**I. THE CONTROL OF QUALITY AND PERFORMANCE
OF ALUMINUM ALLOY AIRPLANE MOTOR
CASTINGS BY X-RAY DIFFRACTION TEST**

**II. STRUCTURAL VARIATIONS IN STEPPED
ELECTRODEPOSITED METAL FILMS**

BY
GEORGE PISH
B.S., Central YMCA College, 1940

AN ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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CHEMISTRY IN THE GRADUATE SCHOOL OF
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URBANA, ILLINOIS
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PART I

THE CONTROL OF QUALITY AND PERFORMANCE OF ALUMINUM ALLOY AIRPLANE MOTOR CASTINGS BY X-RAY DIFFRACTION TEST

INTRODUCTION

For several years the x-ray back-reflection method in the study of materials was more or less of academic interest, but the present war emergency has focused attention upon its application in testing of materials which must undergo extraordinary service conditions of stress, fatigue, temperature variation and overloading. The usual physical methods of testing castings used in airplane engines are out of the question since specimens must be destroyed in some phase of the analysis. Objections to the x-ray method are the lack of suitably calibrated standards for quantitative evaluation from patterns of residual strain in castings and the time required for producing a series of patterns. Transmission methods, of course, are impracticable since cold work is difficult to avoid in the preparation of thin specimens and the castings themselves would have to be cut for these samples.

Measurement by the x-ray method of strains resulting from applied stresses was shown to be possible in 1925 by Lester and Aborn;¹ later the theory^{2, 3} for the calculation of these strains was completed. The back-reflection method has found wide application^{4, 5} since, and the results obtained in the study of strains in metals are found to be in agreement with those obtained by physical methods.

When an increasing tension is applied to any given material, a series of x-ray patterns is obtained which is manifested by diffraction ring displacement, streaking, distortion and blurring of spots for large grains and other changes.⁶

In the present investigation a set of specifications for the processing of castings was determined which produced ultimately an engine that will perform safely under very difficult

conditions. The behavior of 355 aluminum alloy was first studied by stress methods. Then actual castings were investigated to determine methods which would produce uniformly strained or strain-free castings.

EXPERIMENTAL

For the preparation of a set of calibrated series of patterns an apparatus was designed and constructed for applying tensile and compressional stresses to specially prepared test bars. The device was calibrated easily using an Olsen testing machine. In order to obtain exposures in about five minutes by the back-reflection method a focusing technique with large collimating pinholes was used.⁷ Large castings were analyzed in about two hours by this method, from 15 to 20 patterns made in various positions.

The different variables of casting were studied. The melting and pouring temperatures were held constant while quenching fluids were varied (water, oils, Dowtherm). After the proper quench was found, the temperature of the quench was varied as well as the temperature to which the castings were heated before quenching. Finally the conditions of ageing treatment were checked. To further increase the hardness of the castings the effect of iron chills in casting process were studied.

Microradiography^{8, 9} studies were applied to test bar samples in the study of segregation (intermetallic compounds) in the alloy.

After the casting process was developed fully, the effect of sandblasting in castings was examined to determine to what extent it penetrated the surface.

RESULTS

Through the use of the tension-compression apparatus a calibrated series of patterns was developed which could be used in the evaluation of strain in castings by comparison. Study of the various conditions of casting indicated that the

following procedure is necessary to produce a casting having the desired properties:

1. Gas fired furnace used.
2. Castings poured at 440°F into sand molds containing proper iron chills.
3. Solid solution treatment at 980°F for 12 hours.
4. Quenched in A-30 oil (room temp.) or Dowtherm (75°F).
5. Ageing at 440°F for 8 hours.

This combination of casting variables has made possible an increase in effective horsepower for the same weight of motor castings to 1700.

Microradiography experiments showed that segregation of intermetallic compounds could not be distinguished in the best castings indicating almost complete solid solution.

By suitable control of sand pressure and speed of travel of castings in sandblasting equipment the surface effects of strain and fragmentation were minimized to a point where they no longer became a problem.

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STRUCTURAL VARIATIONS IN STEPPED ELECTRODEPOSITED METAL FILMS

INTRODUCTION

A number of studies have been made by electron and x-ray diffraction of complete films on metal produced by electrodeposition, dipping, sputtering vapor, condensation etc. These samples were usually peeled off or the base metal dissolved away by some reagent which presumably would not attack the deposited film. The patterns obtained from this kind of specimen did not necessarily give a true picture of the interface structure but an average or integrated structure through considerable thickness of the deposit. No record has been found where a study was made of carefully graded step-wise thickening films upon a substrate metal from the first invisible layers to the final one of considerable thickness. With this series of specimens the structure at the various thicknesses could be examined without integrating through considerable thickness of deposited film. This is possible by the use of electron and x-ray diffraction methods.

The correlation of optical data of reflections with those obtained by electronic methods was attempted. Such measurements have not been reported previously.

EXPERIMENTAL

Specimens to be step-wise plated were cleaned first and then placed into the proper plating solution (some were given a thin copper flash coat before plating). Electrical contact was made and the entire sheet of metal plated for a definite period of time. Then the sheet was raised out of the solution about one inch, washed by a fine stream of water and the process repeated for another increment of time. This procedure was repeated until the desired number of deposits were obtained.

A combination collimating system and sample holder was designed and constructed which facilitated the holding of specimens at a fixed angle of tilt. This arrangement required the

measurement and setting of the sample-film once only and could be clamped so that the sample-film distance would remain constant for an entire series of electrodeposited specimens.

X-ray and electron diffraction patterns were obtained from the various electrodeposited step-wise series. Reflectance traces were also obtained of the samples using the General Electric Recording Spectrophotometer. The data obtained was studied by plotting reciprocal percent reflectance versus plating time.

Attempts were made to measure the plating thicknesses of the various steps using chemical and physical measurements. Volumetric and microscopic methods, direct weighing methods and x-ray intensity methods were investigated.

RESULTS

By the methods employed it was found that the deposited films upon base materials without orientation followed the random structure throughout the entire thickness of the deposits. On the other hand, those deposited on oriented substrate metals showed orientation also in the initial deposit, but subsequent to this, additional steps no longer showed orientation. In several cases the initial deposited film simulated the structure of the base metal indicating pseudo-basal-isomorphism. The results obtained are in agreement with those found in literature^{1, 2} using electron diffraction methods.

Optical measurements indicate that the base metal exerts a profound influence upon the initial deposited layers and these effects decrease with increasing film thickness, since the layers are farther and farther removed from the influence of the substrate metal.

All attempts to measure the various thicknesses of deposited films failed except in the final layer of each series of the samples studied. On this basis the thickest film studied was about 0.0002 cm. thick.

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VITA

The author was born August 2, 1914 in Chicago, Illinois and received his primary education at Wells Grammar School and his secondary training at Lane Technical High School there. After graduation in January, 1933, he continued his education part time at Central YMCA College and in 1940 received the Bachelor of Science degree. From 1936 to 1940 he was employed by the General Electric X-Ray Corporation in Chicago. In the fall of 1940 he entered the Department of Chemistry of the Graduate School of the University of Illinois. From 1940 to the present he held a teaching assistantship in the Analytical Division.

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